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A Middle Neolithic well from Northern Germany: a precise source to reconstruct water supply management, subsistence economy, and deposition practices

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A B S T R A C T

Wells constitute a seldom, but important archive particularly as a source for reconstructing prehistoric economy. For the newly discovered Middle Neolithic well of the Funnel Beaker North Group at the domestic site of Oldenburg-Dannau LA77 (North Germany), a deposition of settlement refuse in a former well was documented. Due to depositional processes, the remains provided a detailed palaeo-ecological and archaeological archive for a short time-span around 3050 cal BC. The integration of wells in Middle Neolithic water management strategies, the high value of cereal production – including cereal threshing in the settlement and the documentation of a large number of querns – as well as the early management of "fruit gardens" were reconstructed. Subsequently, the probabilities of profane versus ritual social praxis associated with the depositional process were discussed.

1. Introduction

Funnel Beaker Societies (FBC) existed on the Northern European Plain and in Southern Scandinavia from ca. 4100–2800 cal BC. While evidence for human impact and cultivated plants in the FBC-North group is still limited during the Early Neolithic Ia (ca. 4100–3800 cal BC), major economic and environmental changes are documented for the Early Neolithic Ib (ca. 3800–3500 cal BC). First macrofossil evidence for cereal cultivation (Kirleis et al., 2012) coincided with the beginning of a wide scale, supra-regional opening of the landscape (Feeser et al., 2012). The number of domestic sites, causewayed enclosures, and megalithic tombs as well as the quantities of produced items, such as ceramics or adzes, increased rapidly (Müller, 2011). Economic and demographic growth is also documented in the curve of the ^{14}C-dates (Hinz et al., 2012). These developments culminate during the Early Neolithic II (ca. 3500–3300 cal BC) when most of the megaliths were erected. In the following Middle Neolithic (ca. 3300–2800 cal BC) an economic and demographic decline is registered (Hinz et al., 2012; Feeser et al., 2012).

It is to be assumed that access to fresh water was an important factor associated with the Neolithic economy. The water management strategies of prehistoric communities are one aspect of the scientific discourse, which increasingly has become a focus of economic archaeology (e.g. Hamburg and Louwe-Kooijmans, 2006: 42; Lindemann, 2006). Did the shift to agriculture trigger new technologies in water supply management? Did environmental change – especially in the direct surroundings of domestic sites – necessitate new forms of water management? How did these underlying conditions influence the pattern of communal activities of the first farmers?

Although a reasonable number of features connected with water supply management, such as wells, water holes, and springs, are documented for the FBC (e.g. Bakker, 1998; Andersson, 2004; Rudebeck, 2009), our knowledge of water management for the Northern moraine and sandy areas, i.e. the area of the North FBC group, is still minimal. In this respect, the newly discovered well from Oldenburg-Dannau, found within a Middle Neolithic FBC Settlement, and its interdisciplinary investigation involving archaeology, archaeobotany, archaeozoology and palynology, promised new important insights. While functional and structural issues have been and are the main focus of many studies (Koschik, 1998), here questions concerning the significance of water management, the reconstruction of the subsistence economy, and possible ritual aspects of the infilling process will be addressed. What conclusions can be drawn from the finds and evidence on the manner of subsistence in a Middle Neolithic Funnel Beaker settlement? Do the archaeological and the ecological data correlate?

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How can the significance of water management be evaluated for the well in connection with a reconstruction of the environment?

2. Study area

The study area is located at the Baltic coast of Northern Germany within the so-called Oldenburger Graben, an area of 37 km^2 that was shaped by two fjords during the Holocene sea-level rise (Fig. 1). When the sea-level rise slowed down in the Late Atlantic (Late Mesolithic), the coastline was stabilised by a sequential arrangement of cliffs and beach ridges. The former bays and fjords were cut off from the sea by sand barriers and lagoons developed. During the Middle Neolithic (3300–2800 cal BC), i.e. the time period of interest, such a lagoon setting prevailed (Jakobsen, 2004). Dependant on the freshwater supply from the hinterland and the inflow of brackish water during high tides and storm events, these lagoons exhibited a brackish to freshwater environment. In the case of the western part of the Oldenburger Graben, the former bay was cut off from the Baltic by sand barriers. Freshwater was provided by a river which entered the lagoon just 400 m southwest of the investigated settlement (see below) and by a number of smaller inflows around the shore of the lagoon.

Evidence for Mesolithic and Neolithic settlement activity is concentrated along the periphery of the fjord/lagoon as well as on islands and peninsulas. The Middle Neolithic settlement Oldenburg-Dannau LA 77 (cf. also Brozio, 2010, 2011, 2012) is situated on one of these islands, measuring ca. 3 ha in size (Fig. 2).

3. Material and methods

In the summer of 2010, the excavation of the settlement Oldenburg-Dannau (LA77) revealed a long oval feature measuring 1.3 m in diameter beneath the occupation layer (Fig. 3). The feature was located within the domestic site and ranged into a depth of 2.3 m below the Neolithic surface into the glacial sand. Following Bakker's definition (1998), which describes cylindrical pits that reach ground water level and may include casings made from wattle work or hollowed-out tree trunks, the feature was interpreted as a well. In order to gain as much information as possible from this feature, a multi-disciplinary sampling strategy in addition to archaeology was agreed upon after consulting experts on palynology, archaeobotany and archaeozoology.

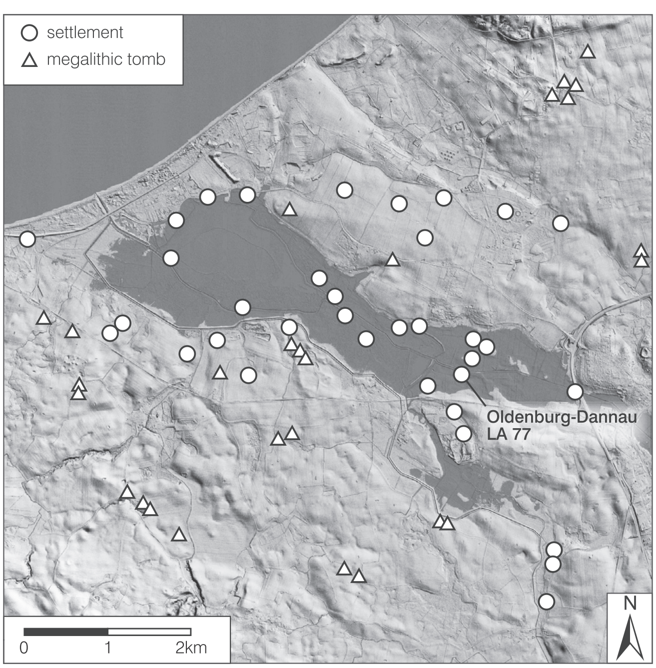

Fig. 1. Neolithic sites in the region of the western "Oldenburger Graben". In addition to Oldenburg-Dannau LA77, further FBC domestic sites and megaliths are mapped.

3.1. Excavation and field observations

The first half of the feature was excavated in a first step. After the identification of the stratigraphy in the profile section, the second half was excavated and sampled in layers (Figs. 3 and 4). The well filling could be differentiated into 13 different layers that were sieved for findings and subsampled separately. The size and weight of the findings were measured as well as the volume of the layers to enable find density calculation (Fig. 12). The well bottom was located 230 cm underneath the former surface of the feature and consisted of a 5–10 cm thick, dark black layer rich in macro-botanical material and charcoal fragments (layer 2) overlying sorted glacial sands (layer 1). It is followed by a grey–black sandy layer with a lot of daub plus organic material (layer 4). In contrast, beside charcoal flakes and organic remains, including animal bone fragments, three layers which follow above (layers 5, 8 and 9) all contained Middle Neolithic artefacts. These included daub, flint artefacts, querns, abraders, and adze fragments. Noteworthy is the presence of a human femur that belongs to a ^{14}C-dated, probably late Early Neolithic burial of a mature woman at a distance of two metres from the well (Brozio, 2012). The upper layers (layers 12 and 13) exhibited – in addition to frequently occurring flint artefacts – partly closed marine molluscs. These represent the youngest anthropogenic depositions in light of the stratigraphical situation. A number of intrusions seen in the profile of these upper layers indicate extraction and refilling processes. Moreover, layers 3, 6 and 7 suggest a collapse of the structure in the compressed glacial sand through a loss in stability during the building of the construction and due to the eroding influence of ground water. No traces of a casing were found even though the depth and cylindrical shape of the feature in relation to its small diameter would have required a casing in the event of a prolonged use. Alternatively, a short time span of usage without a casing has to be considered.

3.2. ^{14}C dating

For absolute chronological dating, ten radiocarbon dates were determined from the different layers. Short lived plant material was chosen to prove the vertical stratigraphic succession of the feature (Table 1).

3.3. Botanical macrofossil analyses

After removal of the archaeological artefacts and bones, the complete filling of the pit was evaluated for an archaeobotanical analysis of macro remains. Altogether 540 L of sediment were examined, divided into 25 samples of uneven volume from eight different layers. As no water-logged preservation of plant remains was observed, floatation was applied to the sediment samples to gain the charred remains which then were caught in a sieve of 0.3 mm mesh size. The heavy residue from flotation was broadly scanned for further remains, but as we dealt with sandy soils that easily release the charred macro remains, there were only insignificant black particles, mainly vitrified unidentifiable charcoal. Sieve residues were dried, sorted and identified with Olympus SZ 51 stereomicroscopes at magnifications of ×10–×40. For validation, the reference collection of modern seeds and fruits at the Institute of Prehistoric and Protohistoric Archaeology at Kiel University was used. Additionally, identification keys like Jacomet (2006), Beijerinck (1947), and Cappers et al. (2006) were consulted.

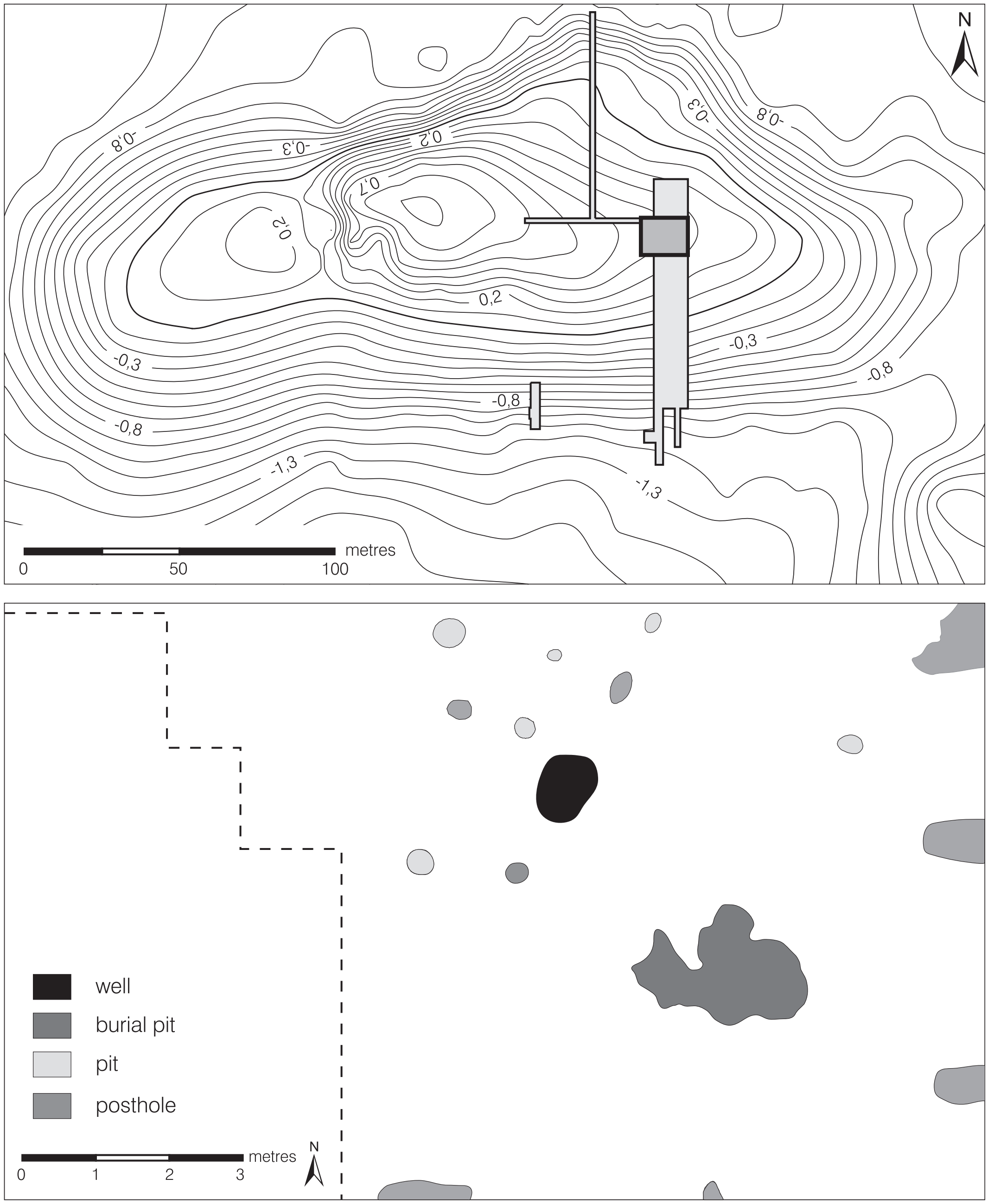

Fig. 2. Excavation trenches (2009/10), Oldenburg-Dannau LA 77.

3.4. Pollen analyses

In total, 11 samples for pollen analyses were taken from the cleaned profile surface during the excavation using sterile syringes. Sample processing followed standard practices, including KOH, HCL, acetolyses, and HF treatment (Moore and Webb, 1991). *Lycopodium* spore tablets were added to allow for a calculation of concentration values (Stockmarr, 1971). The coarse fraction (>120 μm) was removed in an initial sieving and subsequently scanned for macro remains. Pollen samples were finally sieved using ultrasonic and a 5 μm-mesh sieve in order to remove unwanted fine particles. Samples were counted using phase contrast and ×400 magnification. Cereal identification was performed with ×1000 magnification (Fig. 9). Results are presented in a concentration-diagram as counts per g of sediment (Fig. 10) and as a percentage diagram of arboreal taxa and total terrestrial pollen (Fig. 11).

3.5. Archaeozoological analyses

Bones extracted by the sieving of the different layers were cleaned, weighted, measured and determined by Cheryl Makarewicz, Kiel University. Shell fragments of molluscs were identified by Hanno Kinkel, Kiel University.

4. Results and interpretation

4.1. Chronology and stratigraphy

The results of the ^{14}C dating are presented in Table 1. The sequential calibration of the radiometric dates (Fig. 5) suggests short infilling incidents, i.e. the youngest dates are derived from the upper and from the lowest layers of the well. Seven of the dates originate primarily from the flat calibration curve section 3100–

Fig. 3. Well profile showing the concentration of finds in layers 4–5. Photograph: Jan Piet Brozio.

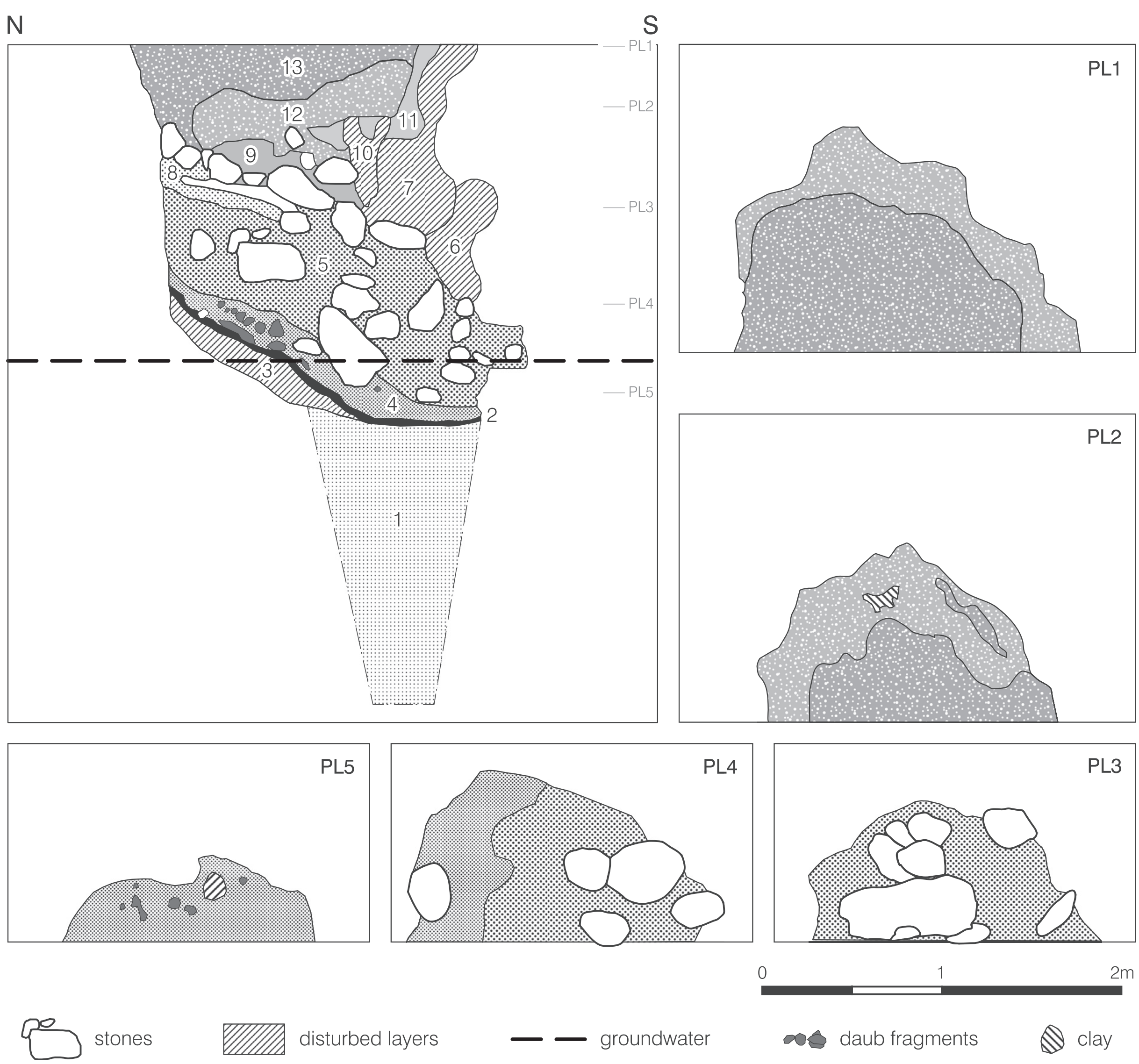

Fig. 4. Eastern well profile. Layer 1 marks the excavation trench into the sorted glacial sand. Drawing: Jan Piet Brozio/Holger Dieterich.

Table 1
Results of the ^{14}C-measurements for the well of Oldenburg-Dannau.

^{14}C lab. no. (Beta-)	Layer	^{14}C age (BP)	δ^{13}C (‰)	Material dated
311575	13	4390 ± 30	−24.3	5 charred grains of *Triticum dicoccum*
311576	9	4450 ± 30	−24.9	5 charred grains of *Triticum dicoccum*
311577	9	4420 ± 30	−23.4	Fruit fragments (incl. seeds) of charred *Malus sylvestris*
311578	9	4400 ± 30	−25.2	Fruit fragments (incl. seeds) of charred *Malus sylvestris*
311579	7	4390 ± 30	−23.7	5 charred grains of *Triticum dicoccum*
311580	5	4390 ± 30	−23.7	5 charred grains of *Triticum dicoccum*
311581	5	4470 ± 30	−23.3	5 charred grains of *Hordeum vulgare*
311582	5	4460 ± 30	−25.2	5 charred grains of *Hordeum vulgare*
311583	5	4420 ± 30	−23.6	5 charred grains of *Triticum dicoccum*
311584	2/4	4400 ± 30	−23.2	Fruit fragments (incl. seeds) of charred *Malus sylvestris*

2960 cal BC, three primarily from 3380 to 3100 cal BC. The latter still have an overlap with the seven younger dates. Three radiocarbon dates of crab apples (*Malus sylvestris*) provide the dates with the best quality and demonstrate one depositional event from the bottom of the pit (layer 2) to almost three quarters of the filling volume with layer 9. Even the date of the uppermost layer 13 is actually not much younger. From the lack of secondarily deposited materials, a mixture with material from earlier settlement activities is not probable. Consequently, the infill process is to be viewed as a short-term event within the 31st c. cal BC, as reflected in the sequential calibration. Thus, the radiocarbon dates are in line with the typochronological expectations associated with the ceramics, which suggest a dating into the subperiod MN II/III, a time span constituting only about 100 years in the 31st c. cal BC.

4.2. Archaeological material

The single layers are characterized by different concentrations of archaeological artefacts (cf. Fig. 12), which represent the well known artefact categories of domestic sites. Daub fragments with a total weight of nearly 6 kg are deposited as larger conglomerates particularly in layers 4–7, with the highest concentration in layer 7. Quern and rubber fragments are found in layers 9, 8, 5, and 4. To be highlighted in this context are 13 querns and two rubbers from layers 4, 5, and 8 (Fig. 6.1). The querns made from granite, diorite, and metamorphic rock are only found as fragments. All working surfaces are roughened by picks and – with the exception of two examples having a convex shape – they all exhibit a concave form. Both recovered rubbers, made from granite and diorite with a convex shape, show grinding marks. Further stone artefacts include

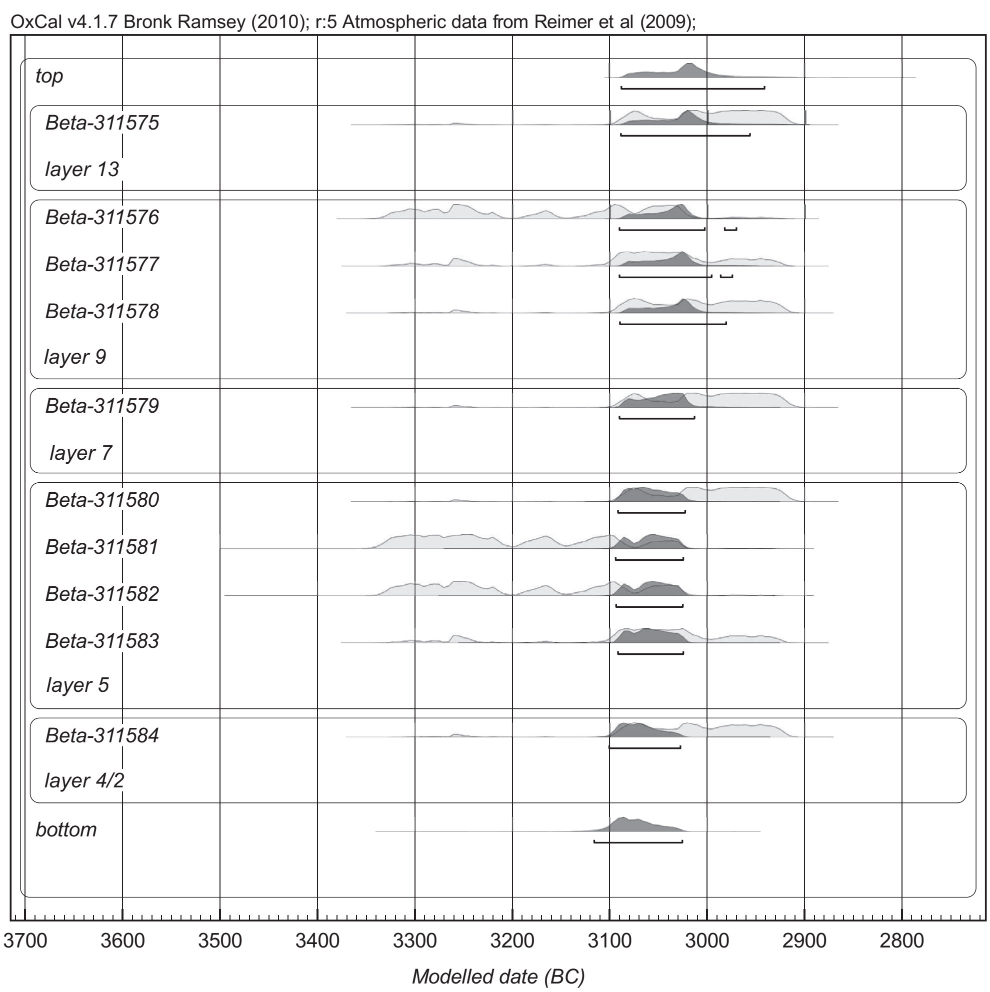

Fig. 5. Chronology of the well: sequential calibration based on 10 radiometric dates.

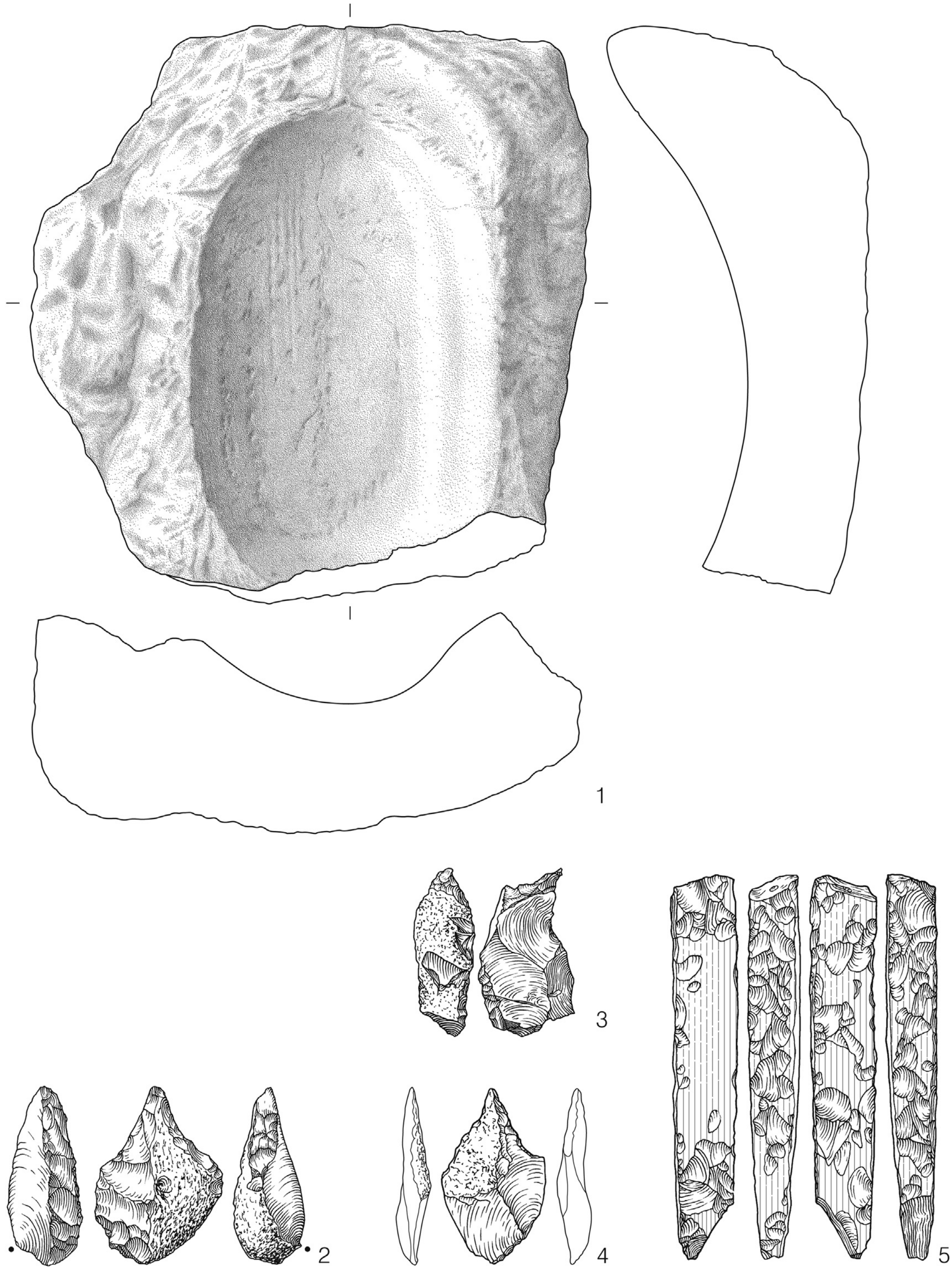

Fig. 6. Selection of flint artefacts and a quern (1–5). Scale 1:2. Drawings: Susanne Beyer//Karin Winter.

26 abrader fragments (sandstone) that are distributed over all layers of the well. Flint artefacts make up the most common group and are also deposited in all layers. The distribution of the basic forms – 423 lithic flakes, 17 blades, and 11 lithic cores with a total overall weight of nearly 10 kg – and tools such as borers, scrapers, chisels, and adze fragments are concentrated in the upper layers (Fig. 6.2–6.5).

As regards ceramics, a total of 189 sherds with a weight of ca. 2.5 kg were found. A minimum number of 10 vessel units could be reconstructed. Among them, two undecorated clay dishes without perforations, one decorated and one undecorated funnel beaker as well as a cone-edged vessel could be identified (Fig. 7). Comparable to the flint artefacts, vessel fragments were observed in all layers, whereas a concentration of ceramics was observed in layer 7. Decorations include an incompletely retained band pattern of slanted lines and slanted hatching marks placed on the outer line. The inner side of the rim of a funnel beaker shows a horizontal row of notches under which an irregular pattern of vertical, angled lines

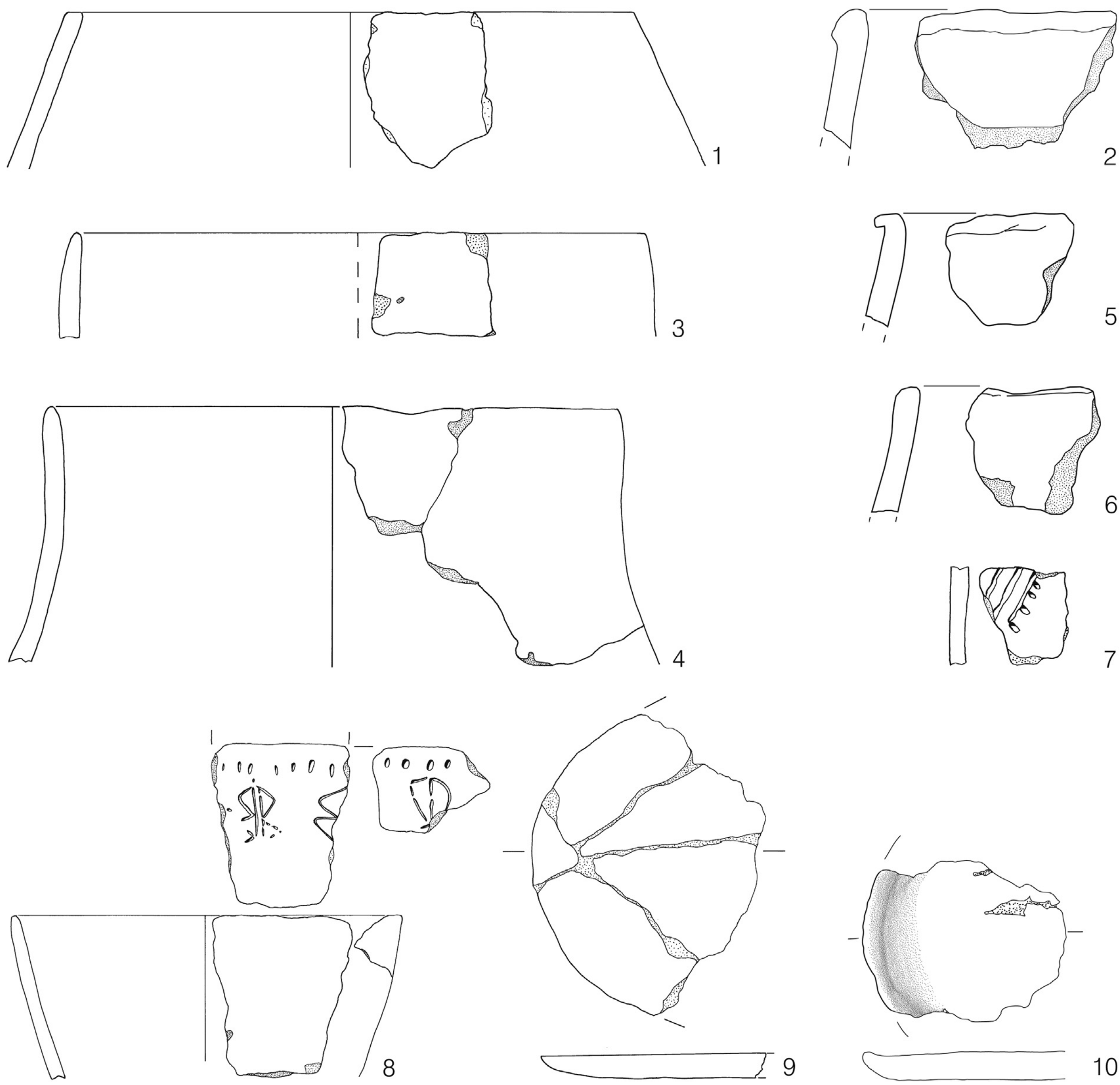

Fig. 7. Ceramics (1–10). Scale 1:4. Drawings: Jan Piet Brozio/Ines Reese.

and simple lines were placed (Fig. 7.8). The typochronologically significant decorations belong to FBC phases MN II–IV (Ebbesen, 1994: 46).

Generally, the archaeological material represents a typical spectrum of domestic waste, which might have been deposited in the abandoned well. The unusual high number of quern fragments may indicate an intentional process, involving the disintegration and subsequent deposition of these artefacts.

4.3. Botanical macrofossil analyses

Charred remains of crops, gathered plants, weeds, ruderals and wetland flora were identified (Table 2). Emmer (*Triticum dicoccon* Schrank, Baier) and naked barley (*Hordeum vulgare* L., *nudum*) are the main cultivated crops. Furthermore, naked wheat (*Triticum aestivum/durum/turgidum*) and einkorn (*Triticum monococcum* L.) are present. Cereal processing is traced through numerous chaff remains. Eye-catching are the whole and cut fruits of crab apple (*M. sylvestris* (L.) Mill./*domestica* Borkh.) with a mean diameter of 2.2 cm (Fig. 8). The charred apple remains are concentrated especially in the lowermost layers of the well. Evidence for other gathered fruits such as hazel nut (*Corylus avellana* L.), raspberry (*Rubus idaeus* L.), blackberry (*Rubus fruticosus* L.), rose hip (*Rosa* L.), and hawthorn (*Crataegus monogyna* Jacq. agg. and *Crataegus laevigata* (Poir.) DC) is rare. Moreover, water chestnut (*Trapa natans* L.) is proven by small hooks of the fruit.

The inventory of weed seeds and fruits is diverse. Especially numerous are the remains of goosefoot (*Chenopodium album* L.) and small grass fruits, e.g. cat's tail (*Phleum pratense* L.) and annual blue grass (*Poa annua* L.). Remains of field brome (*Bromus arvensis* L.), clover (*Trifolium* L.), curly dock (*Rumex crispus* L.), ribwort plantain (*Plantago lanceolata* L.), lady's thumb (*Persicaria maculosa* Gray), black bindweed (*Fallopia convolvulus* (L.) Á. Loeve), fescue (*Festuca* L.), rye brome (*Bromus secalinus* L.), and hairy sedge (*Carex hirta* L.) complement the herb spectrum. Some of these remains, e.g. hairy sedge and curly dock, represent wetland vegetation and possibly grew at the edge of the settlement island.

The distribution of plant remains is not consistent throughout the archaeological layers. In the uppermost layer 13, evidence is limited to cereal grains and few threshing remains (Fig. 12). In

Table 2
Results of archaeobotanical macro remain analyses (absolute countings). Nomenclature follows Erhardt et al. (2008) for the wild plant taxa, crop plants after Schultze-Motel 1986 (Mansfeld).

Layer	13	12	Layer 12 + 13	9	8	7	5	4	2	Layer 2–9	Sum (all)
Sample volume in litre	**8**	**86**	**94**	133.5	**46**	50.5	**160**	30.5	**26**	446.5	540.5
Crop plants (grains)											
Hordeum vulgare L., *nudum*				6			29		45	80	**80**
Hordeum vulgare L.	174	146	320	144	7	13	85	17		266	**586**
Triticum dicoccon Schrank, Baier	17	159	176	563	14	208	280	97	31	1193	**1369**
Triticum cf. *monococcum* L.							2	3	2	7	**7**
Triticum aestivum/durum/turgidum L.				9			1			10	**10**
Triticum L.				10		1				11	**11**
Cerealia indet.	115	245	360	642	65	327	165		10	1209	**1569**
Sum crop plants (grains)	**306**	**550**	**856**	**1374**	**86**	**549**	**562**	**117**	**88**	**2776**	**3632**
Crop plants (threshing remains)											
Hordeum vulgare L., rachis segments				74	11	34	109	16	40	284	**284**
Hordeum vulgare L., glume bases						29					**29**
Triticum dicoccon Schrank, Baier, glume bases	2	126	128	3231	206	832	5432	795	1007	11,503	**11,631**
Triticum dicoccon Schrank, Baier, rachis segments				4		2				6	**6**
Triticum cf. *monococcum* L., glume bases						4	13			17	**17**
Triticum aestivum/durum/turgidum L., rachis segm.				5			6			11	**11**
Cerealia indet., rachis segments				39		5	145		7	196	**196**
Sum crop plants (threshing remains)	**2**	**126**	**128**	**3353**	**217**	**906**	**5705**	**811**	**1054**	**12,046**	**12,174**
Gathered plants											
Corylus avellana L.		1	1	3	1	1	4	1		10	**11**
Crataegus laevigata (Poir.) DC.							1			1	**1**
Crataegus monogyna Jacq. agg.									1	1	**1**
Malus sylvestris (L.) Mill./*domestica* Borkh., seeds				157	1	1	137	75	201	572	**572**
Malus sylvestris (L.) Mill./*domestica* Borkh., fruits				45	2	1	39	26	53	166	**166**
Rosa L.							1	1		2	**2**
Rubus fruticosus sect. *Rubus*				1			1		9	11	**11**
Rubus idaeus L.				1			4		2	7	**7**
Trapa natans L., spine barb							2	1	1	4	**4**
Sum gathered plants		**1**	**1**	**207**	**4**	**3**	**189**	**104**	**267**	**774**	**775**
Weeds											
Aphanes arvensis L.									2	2	**2**
Bromus cf. *arvensis* L.				27	1	4	32	8	21	93	**93**
Bromus cf. *secalinus* L.				4			6			10	**10**
Bromus L.							1			1	**1**
Chenopodium album L.		4	4	105	11	25	491	400	197	1229	**1233**
Chenopodium ficifolium Sm.							1			1	**1**
Echinochloa crus-galli (L.) P. Beauv.							2	1	1	4	**4**
Festuca L.				1				1	10	12	**12**
Galium L.								1		1	**1**
Lapsana communis L.							1			1	**1**
Lolium temulentum L.							4			4	**4**
Lolium L.				1				3		4	**4**
Phleum pratense L., s.l.				25			49	6	20	100	**100**
Plantago lanceolata L.				3			12	3	2	20	**20**
Poa annua L.				1		3	24			28	**28**
Polygonum aviculare L., agg.								1		1	**1**
Fallopia convolvulus (L.) Á. Löve				3			8	1		12	**12**
Persicaria maculosa Gray				4			3	2	9	18	**18**
Ranunculus sp.							2			2	**2**
Rumex acetosella L., agg.							2			2	**2**
Solanum nigrum L.							1			1	**1**
Stellaria media (L.) Vill., agg.				1			3	1		5	**5**
Trifolium L.				7			23	2	7	39	**39**
Vicia L.				1			5		1	7	**7**
Viola L.							1			1	**1**
Sum weeds		**4**	**4**	**183**	**12**	**32**	**671**	**430**	**270**	**1598**	**1602**
Wetland plants											
Alnus cf. *glutinosa* (L.) Gaertn.							1	1		2	**2**
Atriplex hastata L.				3			1			4	**4**
Carex disticha Huds.							1			1	**1**
Carex hirta L.				1			3		6	10	**10**
Carex vulpina L.							2			2	**2**
Carex L., bicarpellat				1			1	1		3	**3**
Carex L., tricarpellat		1	1	2						2	**3**
Mentha L.				1						1	**1**
Persicaria hydropiper (L.) Delarbre							3			3	**3**
Persicaria lapathifolia (L.) Delarbre, agg.				3						3	**3**
Rumex crispus L.						1	15	3	3	22	**22**
Schoenoplectus (Rchb.) Palla							1			1	**1**
Sum wetland plants		**1**	**1**	**11**		**1**	**28**	**5**	**9**	**54**	**55**
Others											

Table 2 (*continued*)

Layer	13	12	Layer 12 + 13	9	8	7	5	4	2	Layer 2–9	Sum (all)
Asteraceae							1			1	**1**
Brassicaceae							1			1	**1**
Caryophyllaceae						1	3	1		5	**5**
Cyperaceae				1					2	3	**3**
Fabaceae				1						1	**1**
Lamiaceae		1	1			1				1	**2**
Poaceae		6	6	201	13	34	427	129	195	999	**1005**
Sum others		**7**	**7**	**203**	**13**	**36**	**432**	**130**	**197**	**1011**	**1018**
Codling moth (Cydia pomonella), caterpillar				3			1	1	11	**16**	**16**
Sum (all remains)	**308**	**689**	**997**	**5334**	**332**	**1498**	**7588**	**1598**	**1896**	**18,246**	**19,243**

layers 7, 8, and 12, the occurrence of plant remains is more balanced between cereal grains, threshing remains, weeds/herbs, and gathered plants. Crab apple remains are represented in layer 9 and particularly in the lowermost layers 2, 4, and 5. In the layers with high amounts of apples, threshing remains as well as seeds and fruits of weeds, grassland and wetland plants also show high values (Fig. 12).

4.4. Archaeozoological analyses

Preliminary analyses of animal bones indicate the deposition of bones (skull, forelimb, hindlimb, vertebral column, and extremities) from at least 6 individuals: 3 cattle (*Bos* sp.), 1 goat/sheep (*Capra hircus*/*Ovis aries*), 1 pig (*Sus scrofa*) and possibly 1 elk (*Alces alces*), scattered over all layers. As 20% of the bones are burnt and 4% indicate cut marks, they represent usual domestic waste. Thus, butchering and consumption took place within the site Oldenburg-Dannau LA77. In layers 7 and 12, molluscs of the species brackwater cockle (*Cerastoderma lamarcki*), baltic tellin (*Macoma balthica*), and common periwinkle (*Littorina littorea*) were found (Fig. 12). The bivalve shells were still partly connected in pairs. They indicate the gathering of additional resources for subsistence, most possibly from the marine environment along the coast.

4.5. Pollen analyses

Due to low pollen concentrations, only small pollen sums were achieved (average 45, maximum 168 terrestrial pollen grains). Pollen and non-pollen-palynomorph concentration curves are presented in Fig. 10. Relative abundances of taxa for the combined pollen spectrum of the analysed samples are shown in Fig. 11. An overview of the main results is given in Table 3.

A consideration which has to be regarded when interpreting pollen spectra from minerogenic deposits are taphonomic processes, i.e. the differential corrosion of pollen (Havinga, 1984). In minerogenic soil samples, corrosion resistant taxa such as *Pinus*, *Tilia*, and Liguliflorae tend to be strongly overrepresented, while other taxa, originally only present in comparatively low quantities, might be completely missing, cf. *Fraxinus*. Furthermore, problems regarding the interpretation of rare types, i.e. taxa only recorded with a single pollen grain in the sample, apply in this context to most of the recorded taxa.

Generally, of all arboreal taxa *Alnus* is best represented in the overall pollen spectrum. This indicates the presence of alder dominated wetlands in the vicinity of the settlement, although only one macro remain is found in layer 5 (Table 2). Other arboreal taxa include important elements of the natural vegetation, i.e. species of the mixed oak forest. *Fagus* and *Carpinus* pollen presence is observed, in accordance with the species regular first occurrence in the wider area at the beginning of the Subboreal (Wiethold, 1998). *Pinus* pollen is strongly overrepresented in the spectrum because it is still identifiable although highly deteriorated. The ratio of non-arboreal (NAP) to arboreal pollen (AP) reflects an open environment in and around the settlement. In some cases, very low pollen concentrations, i.e. in layers 2, 4, 9, and 13, do not allow any detailed conclusions. Sample SED 293 (i.e. layer 2) and sample SED 294 of layer 4, however, show increased records of micro-charcoal, which correlates well with the high macro-charcoal contents of these layers. This suggests the disposal of burned/charred debris, in which previously existing pollen might have been destroyed by fire.

Samples relating to layers 4, 5, and 8 partly reflect the pollen spectra from soil material originating from the settlement context as shown by the overrepresentation of corrosion resistant taxa such as *Tilia*, Liguliflorae, and *Pinus*.

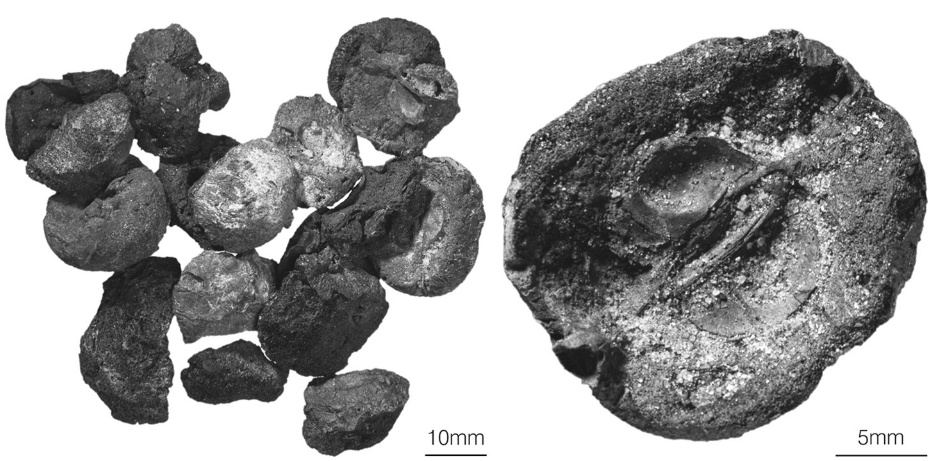

Fig. 8. Charred crab apples. Photographs: Sara Jagiolla.

Table 3
Selected results from pollen samples. Estimation of the abundance of macrofossils from residue (>120 μm): rare (−), (−), frequent (±), (+), abundant (++). Nomenclature follows Beug (2004).

Layer	Sample nr.	Characteristics		Interpretation
		Microfossils	Macro remains	
13	SED 284	Cereal-type pollen	Mollusc fragments (+) Charcoal (−)	−
12	SED 285	Highest pollen concentration Lack of taxa of mixed oak forest High freshwater algae High abundance of indicators of open/disturbed habitats, e.g. Poaceae, Liguliflorae, presence of *Polygonum aviculare*-type High *Pinus* Cereal-type pollen	Fragments of marine molluscs (+) Charred material (−)	Pollen indicates open disturbed habitat, i.e. settlement context The lack of *Quercus* and *Tilia* pollen in combination with a generally high pollen concentration/ preservation suggests: a) The pollen spectrum does not originate from soil context in which the corrosion resistant pollen of *Tilia* would be expected to be overrepresented b) *Quercus* is missing, because this sample represents a seasonal pollen spectrum (autumn − early summer) High algae and aquatic pollen (*Sparganium*-type) concentration suggests freshwater input
9	SED 286	Very low pollen concentration	Charcoal and charred material (±)	−
8	SED 287	High Liguliflorae High micro-charcoal Cereal-type pollen	Charred material (−)	Similar to Layer 5
5	SED 288	AP dominated spectra	Charred material (−)	Infill of soil material, pollen spectrum influenced by taphonomic processes, i.e. evidence for differential preservation
	SED 289	High *Filipendula* Cereal-type pollen	Charcoal and charred material (±)	
	SED 290	High *Filipendula* Cereal-type pollen	Charred material and charcoal (+) Bone fragment (−) Mollusc fragments (−)	High *Filipendula* values might indicate contemporaneous flowering of *F. ulmaria* during infill process. This species is flowering from June−August according to Oberdorfer (1994)
	SED 291	High cereal-type pollen	Charred material and charcoal (−)	Cereal-type pollen (often found in clumps, cf. Fig. 10) introduced with grinding stones
4	SED 292	AP dominated spectra	Charred material and charcoal (−)	Soil infill, not homogeneous
	SED 294	AP dominated spectra High micro-charcoal Cereal-type pollen	Charcoal (++)	
2	SED 293	Low pollen concentration High micro-charcoal	Charred fragments of *Malus sylvestris* (++)	Layer of burned material, mainly *Malus sylvestris*

AP: arboreal pollen.

The comparatively high representation of some NAP taxa in isolated spectra could indicate the selective inclusion of flowering plant material or pollen, respectively in parts of the infilling. Hereby, the lack of evidence for these taxa in other spectra could indicate a seasonal component at the time of infilling, in addition to the pollen background deriving from the soil material which accumulated over a longer time period.

Two samples of layer 5, SED 289 and 290, both characterized by a comparatively high number of recorded pollen and fern taxa, are noteworthy in this context. They contain pollen of *Filipendula*, *P. lanceolata*, *Artemisia*, and *Bidens*-type. Additionally, sample SED 290 is characterized by a high concentration of *Spergularia*-type. All these taxa, except *Filipendula*, indicate highly disturbed habitats and are therefore regarded to reflect the local vegetation within the settlement area. The high representation of *Filipendula*, probably *Fallopia ulmaria*, suggests that the infilling occurred during the flowering season of this species (June–August; Oberdorfer, 1994). Furthermore, *Filipendula* indicates the presence of open wet grounds and thus supplements the macro remain finds of diverse *Carex* species and curly dock (*R. crispus*) in layer 5 (Table 2).

Hordeum- and *Triticum*-type cereal pollen (sensu Beug, 2004) is present in most samples and is regarded to reflect cereal processing in the settlement. It is unlikely that the pollen originated directly from cultivated areas, as the pollen dispersal of self-pollinated cereals is poor. Furthermore, cereal-type pollen in layer 5, which is generally characterized by comparatively high values, was often recorded in clumps (Fig. 9). This suggests that cereal-type pollen was introduced with the querns, which are abundant in the corresponding layer (Fig. 12). A correlation with the numerous charred threshing remains (Table 2; Fig. 12) is less probable as there is no indication for burning of the pollen grains.

The pollen spectrum of layer 12 differs from the samples described thus far. Besides having the highest pollen concentration and a comparatively high number of microfossil taxa, there is evidence for the input of an aquatic component, namely high records of freshwater algae (*Pediastrum* and *Botryococcus*) and pollen of aquatic and wetland species (*Sparganium*-type and Cyperaceae). Considering the high pollen concentration and good pollen preservation, missing evidence of the corrosion resistant *Tilia* pollen suggests that the pollen spectrum does not originate from the soil context. If this were not the case, *Tilia* would have been overrepresented. The lack of *Quercus* pollen may be the result of a seasonal pollen deposition during autumn to early summer, when oak is not flowering. Additionally, the NAP record in layer 12 is characterized by typical indicators of anthropogenic agricultural activities, i.e. high Poaceae and Liguliflorae concentrations and the presence of *Plantago lanceolata* and *Polygonum aviculare*-type.

5. Interpretation and discussion

The Middle Neolithic (ca. 3300–2900 cal BC) settlement of Oldenburg-Dannau LA 77 was situated on an island within the lagoon of the western Oldenburger Graben (Brozio, 2010, 2011). It is assumed that the initial construction of the well was a reaction to brackish water conditions in the settlement near the lagoon, caused by temporary salt water incursions into the lagoon of the Oldenburger Graben. A short period – probably not longer than half a century – of increased salinity (represented by high values of *Hystrix*) in the lagoon during Neolithic times is also suggested by pollen-analytical studies (Venus, 2004). However, long-term usage of the well was not necessary as the closure of the lagoon around 3000 cal BC led to the subsequent desalination und restoration of fresh water conditions (Jakobsen, 2004: 109f.).

Another, contrary scenario would suggest that the well was already used during the main phase of the settlement and its abandonment was linked to changing environmental conditions. Hereby, a period of increased salinity not only of the lagoon water, but also of the island's ground water, could have led to a shortage of freshwater, which subsequently resulted in a decline of domestic activities. The lack of any casing and the evidence for lateral collapses of the walls (cf. layers 3, 6, and 7) additionally suggest a rather short usage of the structure as a well.

Subsequently, the well was used for disposal purposes. As indicated by ^{14}C dating, the possible seasonal pollen component in the layers, and similar find/artefact composition, e.g. layers 2 and 9, the infilling occurred over a rather short time period, probably just representing a single deposition process, involving different infill layers. The uppermost layers 12 and 13 show signs of re-use or temporary use as a flatter pit. The ^{14}C datings, however, suggest that these events happened rather contemporary to the previous infilling events. The palynological data, i.e. the presence of freshwater algae, suggests fresh water input in layer 12. In context of the sandy bedrock, which argues against the possibility of prolonged periods of in-situ standing water, an anthropogenic input of water seems likely. This may be explained by its utilization as a cooking pit. In this context, the mollusc remains could be interpreted as remains of food processing.

The interdisciplinary investigations of the well and its sequential change of function from a structure for a) water management to b) a disposal pit offer the possibility to gain further

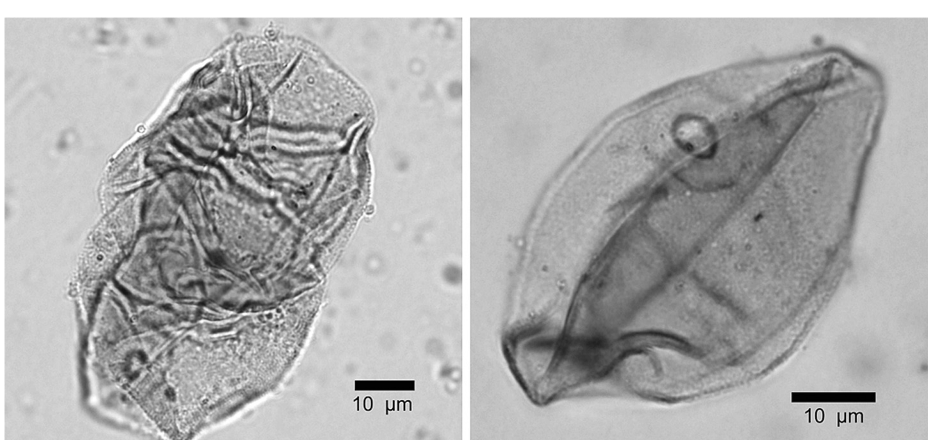

Fig. 9. Cereal-type pollen from layer 5 (SED 291). Left: clump of cereal-type pollen. Right: single cereal-type grain.

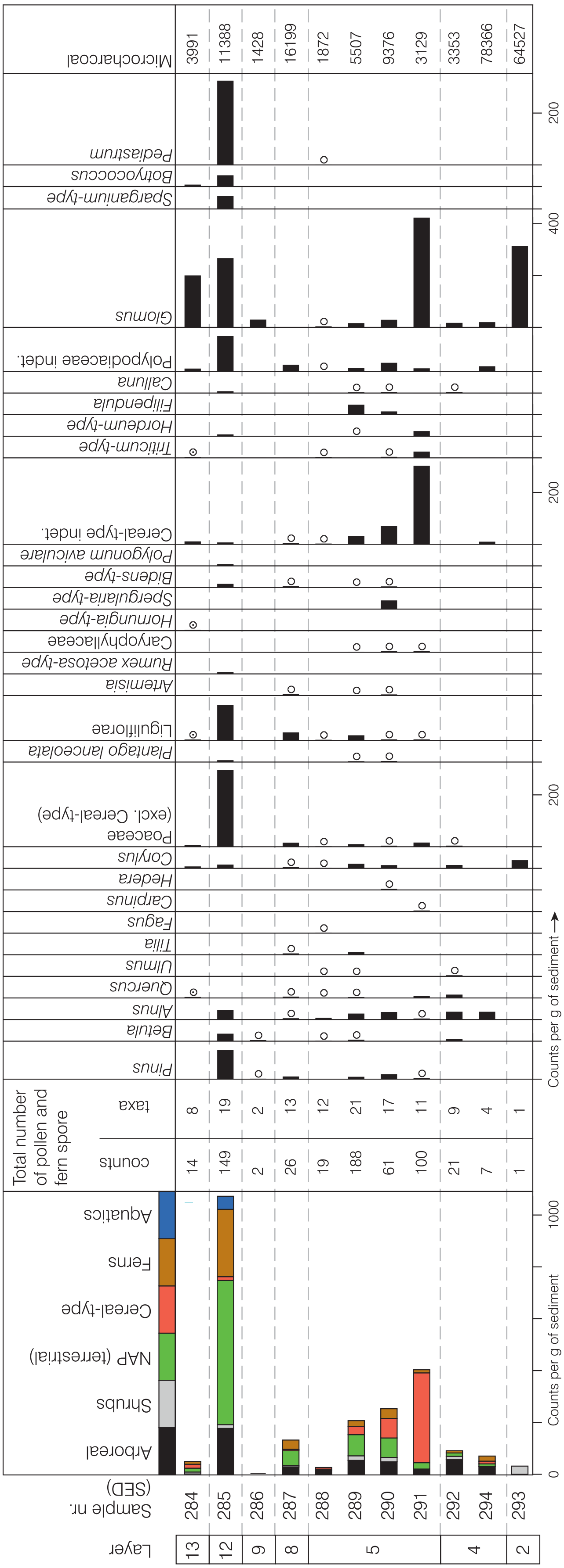

Fig. 10. Concentration pollen diagram, showing selected pollen and non-pollen-palynomorph taxa.

insights into different aspects of Neolithic life. Its function as a well in combination with the environmental data helps to improve our knowledge of "water management" in Neolithic settlements (cf. chapter 5.1). The subsequent refilling with sediments containing artefacts and organic remains from a settlement context give information on subsistence strategies (cf. chapter 5.2). Finally, the evidence of finds usually not associated with ordinary domestic waste, i.e. the high number of querns and a human bone, raise the question whether ritual deposition practices might have also been involved (section 5.3).

5.1. Water management

The discovery and excavation of the well of Kückhofen from the Linear Band Ceramic period, with the dendrochronological dates 5090, 5067 and 5050 den. BC and its outstanding carpentry technology, has led to enhanced interest in "wells" in archaeological research (e.g. Weiner, 1998). Despite a growing number of known water holes and wells, there are only a few precisely dated and multi-disciplinary investigated Neolithic wells. This also holds true for the FBC North Group.

In the area of the North Central European- and Southern Scandinavian FBC, water was generally withdrawn from surface water, to which the sites (including Oldenburg-Dannau) exhibit a regular connection (Mennenga, 2011). Furthermore, water holes and cylindrical pits/wells were used to extract drinking water (e.g. Bakker, 1998). Beside the extraction of water, ritual depositions regularly took place in wells, wetland areas or at the edge of water bodies. At least 85 such sites with vessel depositions were identified in the FBC area (Bakker, 1998: 154, Fig. 3). Archaeologically, it is not easy to differentiate between such deposition places and those which only served the purpose of water provision. To date, wells from 13 sites are known for the FBC (Fig. 13; compare also Bakker, 1998: 155 and 156, Fig. 4). These include cylindrical pits that reach ground water level, which may or may not have casings made from wattle work or hollowed-out tree trunks. Springs or natural water holes with ceramic finds are not included. Apart from Mesolithic water holes (Gramsch, 1998) and Neolithic wells from the Netherlands (Hamburg and Louwe-Kooijmans, 2006), these wells provide the oldest indications of systematic drinking water management in North Central Europe and Southern Scandinavia. If we functionally differentiate between recurrently dug and artificially shaped water holes and cylindrically dug wells, the latter can first be documented for the FBC North and West groups beginning in the period FN Ib/FNII (thus, at approx. 3600 cal BC; compare references to Fig. 13). Apparently, digging water holes and constructing wells go hand in hand with changes such as the introduction of the plough, and the construction of megalithic tombs and enclosures. We are dealing with a timeframe in which strong cultural, economic, and environmental changes occurred: monumentality in the form of megaliths and enclosures developed, the introduction of the ard, and increased settlement activities are documented, whereby an opening of the landscape in connection with increased cereal cultivation is observable (Feeser et al., 2012; Kirleis et al., 2012).

Unfortunately, most of the wells have only been published in preliminary reports and just a few of them have been investigated using a multidisciplinary approach (e.g. Kolhorn, late Single Grave Culture, The Netherlands, cf. van der Waals, 1989). Features comparable to the well from Oldenburg-Dannau are known for Almhov and Saxtorp 23 (Southern Sweden) and from Schipluiden (The Hague, The Netherlands).

In Saxtorp 23 (Andersson, 2004: 54–56), a promontory-like tongue (10 m a.s.l.) was used by a Funnel Beaker community as a domestic site. Two small and shallow pits (diameter: ca. 1 m; depth: ca. 0.4 m) were interpreted as wells, because they reached ground

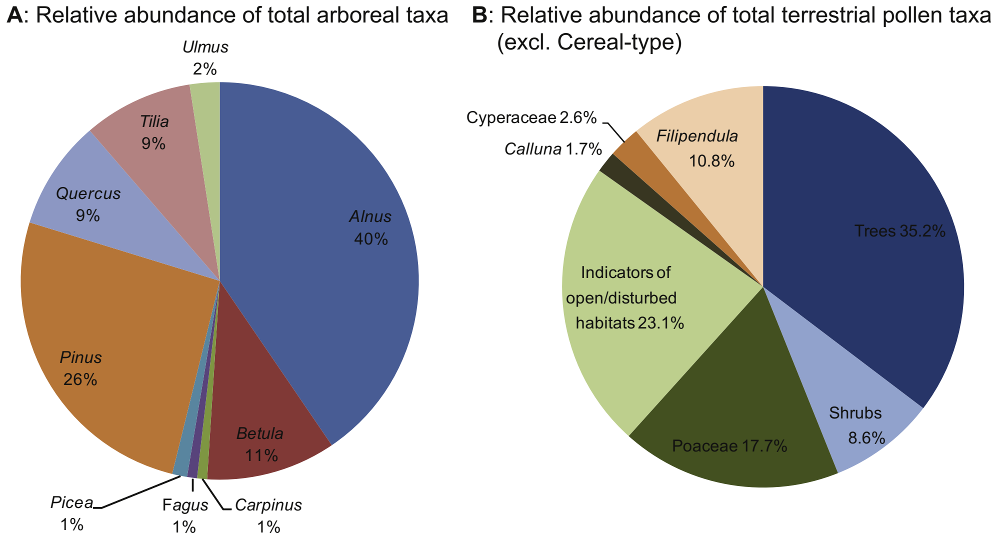

Fig. 11. Relative abundance of arboreal taxa (A) and terrestrial taxa, excluding cereal-type pollen, which is regarded to have been mainly introduced with querns, (B) of combined pollen data from all analyzed samples.

water level. These wells are situated 60 m to the west of a house and 80 m to the north of flat graves.

In the Funnel Beaker settlement Almhov (FNII–MNA), two features were found and interpreted as wells (Rudebeck, 2009: 98–99 and 112–113). One of them was situated under an oval house (measuring 12–14 × 6–8 m) and was ca. 1.7 m deep (Rudebeck, 2009: 151–152, Fig. 6). The slightly conical shape with an upper width of 3.3 m indicates supplementary digging instead of a framework (Rudebeck, 2009: 101, Fig. 5).

In Schipluiden, a domestic site of the Hazendonk group (ca. 3600–3400 cal BC) near the Dutch North Sea coast, an overall number of 148 pits (40–370 cm in diameter and 30–200 cm deep) that reach the groundwater level were interpreted as wells (Hamburg and Louwe-Kooijmans, 2006). They are concentrated at the edge of the settlement but they also occur in between the houses at higher elevations. The settlement was located at a dune in the Rhine River estuary. With one exception, no casings were found in the wells. As these wells each had a bipartite filling, they seem to have been in use for just a short span of time. A first infill was maintained by natural, more or less clean sand shortly after they had been dug. The second fill is interpreted as an extension of occupation layers of the surrounding settlement. The wells are additionally interpreted as temporary sources of freshwater. It is maintained that a lens of freshwater originating from rainfall floated on top of the brackish to saline groundwater beneath the dune (Hamburg and Louwe-Kooijmans, 2006). As one explanation hypothesis the authors write "…that there was usually a sufficient supply of freshwater, but that that supply was incidentally threatened, notably when the sea forced its way inland during storms and/or spring tides. After a flood, such pits will have constituted a quick solution for bridging the time to the recovery of the former situation" (Hamburg and Louwe-Kooijmans, 2006: 43).

Comparing the situation at Oldenburg-Dannau with the sites in Southern Sweden, different intra-site spatial patterns become obvious. In Saxtorp 23, a spatial division of the area with wells, houses and burials at a distance from each other can be observed. In Almshov, wells are situated at the edge of the domestic area. In FBC Oldenburg-Dannau and Hazendonk Schipluiden, however, the wells are centrally located within the settlement. With regard to the spatial organisation as well as the type and potential primary function of the wells, these two latter sites are suitable for comparison. In Oldenburg-Dannau, the well also is interpreted as a temporary source of freshwater during a time of saltwater intrusion. Thus, the question remains open whether different spatial organizing principles existed in the FBC with respect to water management.

5.2. Subsistence economy

Domestic sites as archaeological units have to be considered as economic spaces within the Neolithic landscape. Thus, plant and animal remains from settlements have the highest potential for a reconstruction of early economies. Whereas archaeozoological investigations document expected aspects such as animal husbandry, hunting, and gathering (e.g. Steffens, 2005, 2007; Hartz et al., 2007), the well in Oldenburg-Dannau LA77 is an exceptional feature from an archaeobotanical point of view. The infill material is composed primarily of charred plant remains, including material that is rarely detected for the Funnel Beaker Neolithic so far: threshing remains and apples (Table 2). Thus, the archaeobotanical findings extend our knowledge about the plant economy, summarized in Kirleis et al. (2012).

In general, the Funnel Beaker plant economy can be characterized by the cultivation of barley and emmer as main crops. Cereal cultivation was supplemented by the use of einkorn and naked wheat. There is no evidence for flax cultivation, whereas the only detected oil plant is opium poppy that appeared in the Late Middle Neolithic (MN V) plant assemblages from the waterlogged site Wangels LA505 in the immediate neighbourhood of Oldenburg-Dannau LA77 (Kroll, 2007). Legumes are absent in the Funnel Beaker plant economy, so that first Northern German finds of pea date to the Younger Neolithic and are related to the transitional phase of the Late FBC/Single Grave Culture at the earliest.

5.2.1. Cereal production and processing

Naked barley and emmer were the main cultivated crops, which is also the case in most other FBC settlements in the Northwest European Neolithic (Kirleis et al., 2012). Due to the situation of the settlement on a small island in the wetland area, fields must have been situated on the neighbouring smooth slopes of the lowland at a distance of approximately 2–3 km.

As numerous threshing remains are reported from the well's infill, it is necessary to examine cereal processing activities in Oldenburg-Dannau LA77. Threshing remains of emmer and barley

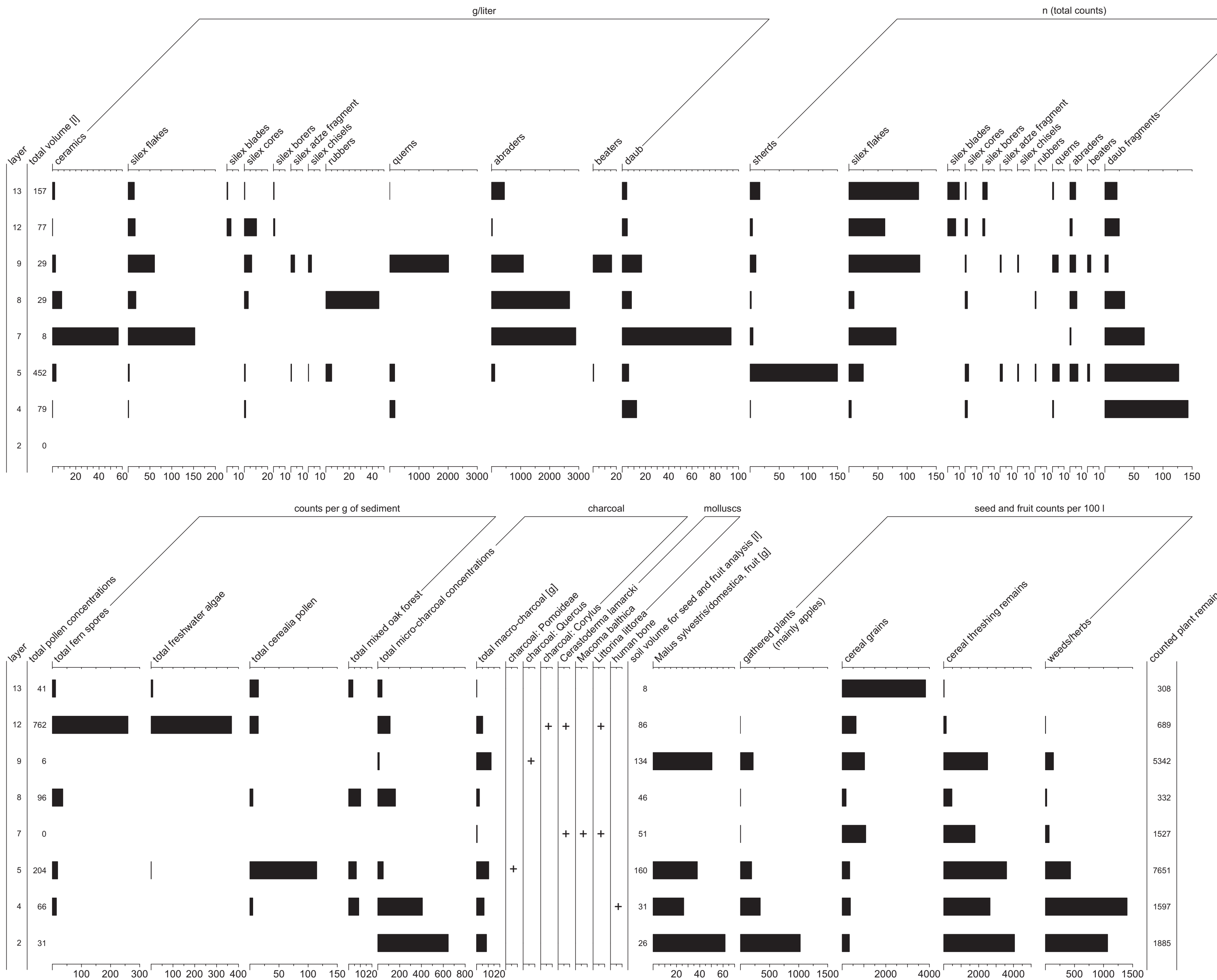

Fig. 12. Stratigraphic overview compiling artefacts, pollen, charcoal, molluscs and botanical macro remains.

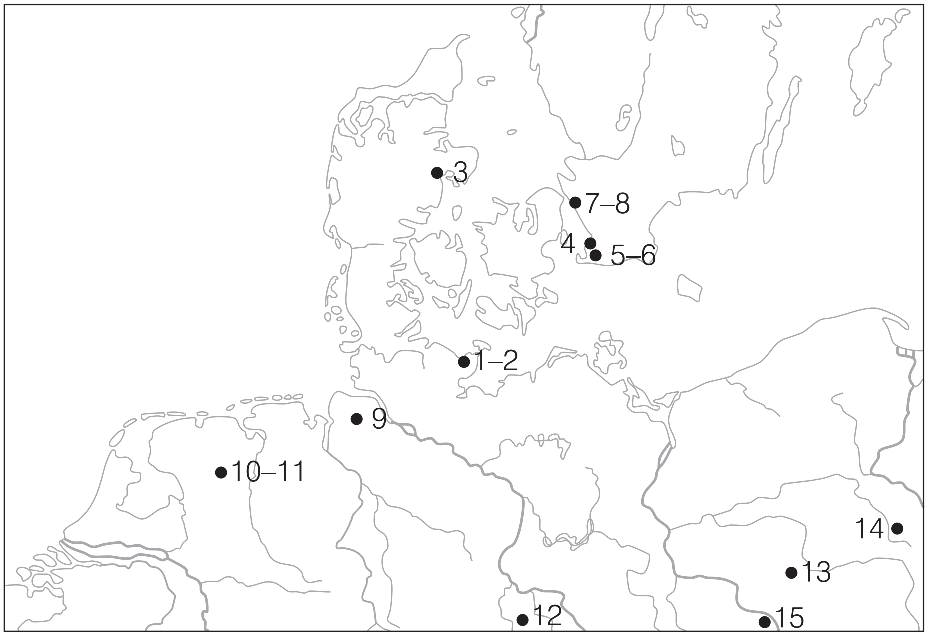

Fig. 13. Wells. Western, northern and eastern FBC groups: 1–2 Oldenburg-Dannau LA77. 3 Kildevang (Ravn, 2005; Skousen, 2008). 4 Hyllie (Sandèn and Andréasson, 2008, 2010). 5–6 Almhov (Rudebeck, 2009). 7–8 Saxtorp 23 (Andersson, 2004). 9 Lavenstedt (pers. comm. M.D. Mennenga, Wilhelmshaven). 10–11 Emmerhout (van der Waals, 1998: 174–176). 12 Brehna (Rachhaupt and Schunke, 2010: 37). 13 Kokorzyn (Bakker, 1998). 14 Swiatniki (Bakker, 1998). 15 Wroclaw-Pracze (Bakker, 1998). Not on the map: 16 Kyjov (Bakker, 1998). 17 Mokelnice (Bakker, 1998). Figure: Holger Dieterich.

dominate the plant assemblages of layers 2–9. They exceed finds of grains by more than 9000 pieces (Table 2) and allow for an interpretation of this filling as rubbish. The occurrence of glume bases from hulled emmer wheat is quite common for Neolithic threshing remains. They are regularly detected in charred plant assemblages dating to the Early Neolithic Linearband ceramics (LBK, e.g. Kreuz, 2012; Kreuz, 1990; Kirleis and Willerding, 2008; Bogaard, 2011). However, rachis segments (parts of the central stalk within the cereal ear) are underrepresented or even missing in the archaeobotanical record, since the rachis was usually separated from the grain by early processing stages which normally took place outside the settlements (Bogaard and Jones, 2007, 363). Ethnographic studies show that – particularly in areas with wet climates – hulled cereals were usually stored as semi-cleaned spikelets or as whole ears after a minimum large-scale processing. Pounding and sometimes even the threshing was undertaken piecemeal, as required, within the domestic site. It took place in the vicinity of the house as a basic economic unit. In wet areas, pounding was preferably carried out indoors (Hillman, 1981, 138). The charred macro remains of crops and weeds, cereal pollen and querns in the well feature of Oldenburg-Dannau LA77 represent residues from daily food preparation when the grains were expelled from the hulls inside the settlement by threshing, dehusking, pounding, sieving, drying, grinding, etc. The glume bases appear as threshing remains from emmer and indicate the storage of emmer spikelets. In contrast, rachis segments of barley can also be observed that hint to a storage of whole barley ears and indicate subsequent further processing within the settlement. Finds of tiny rachis segments of emmer from the highest part of the ears particularly illustrate the very good preservation conditions of the charred material (cf. Hillman, 1981).

Herb seeds and fruits can represent the local ruderal vegetation and possible weeds of the fields that were brought into the settlement during the harvest. With the very high number of altogether 1600 charred weed remains in layers 2–9, this feature is exceptional for the Funnel Beaker period. Fortunately, weeds are associated with a wide range of characteristics. For example, differentiation is possible for summer versus winter grown weeds, annuals versus perennials, vegetative versus diaspore reproduction types, for ecological indicators after Ellenberg, or for different ecological groups and strategies (competitors, ruderals) (Kreuz and Schäfer, 2011; Bogaard, 2004; Bogaard and Jones, 2007). But former field management systems and the appearance of Neolithic crop fields are still difficult to trace. The interpretation becomes even more complex if the potential use and consumption of many wild plants, including the gathering of weeds, is considered (Kroll, 2013, 234). In their compilation and analyses on weed finds as indicator species for the LBK, Kreuz and Schäfer (2011, 346) finally conclude that weed assemblages from sites, where presumably intensive agriculture by the use of the hoe or digging stick was applied, are hardly distinguishable from assemblages of sites, where presumably extensive ploughing was carried out.

In Oldenburg-Dannau LA77, the weed species from layers 2–9 account for summer grown crops as goosefoot dominates the spectrum (Table 2). However, high numbers of goosefoot diaspores may as well account for gathering of this highly productive, edible plant (Behre, 2008; Stokes and Rowley-Conwy, 2002). So far, for the Funnel Beaker period, plant gathering was more highly recorded for the Early Neolithic (3600–3300 cal BC). Later on, gathered plants are still present but lose importance if the economic sphere (domestic sites) is considered (Kirleis et al., 2012, Fig. 8). Remarkable is the high number of tiny diaspores from the perennial plants cat's tail and ribwort plantain (122 diaspores) that grew on the field together with the crops. The perennials show that extensive ploughing with the ard was carried out. The ard simply scratches furrows into the soil without turning the topsoil upside down. Thus, the space in between the furrows is not disturbed and offers optimal conditions for the growth of perennials. They spread further on fallow land that was used for animal grazing (Willerding, 1986: 166, 184).

5.2.2. Apple tree exploitation

The high amount of charred apples shows that crab apples were an important wild fruit, not only used for hand-to-mouth consumption, but also preserved as a stock for a longer period, e.g. as winter stocks. Whole fruits and fruits cut lengthwise in two halves

were recognized in the material. No fresh cracks were observed on the charred apple fragments. In contrast, on some of the fruit halves the epidermis is curved inside which hints to the beginning of the parching process of the fresh fruit halves. Presumably, the apples were intended to be dried in a cupola furnace of clay as characteristic fragments of burnt clay were found together with the apples in layer 4 (Fig. 12). Thus, this layer may represent a desiccation accident.

Light-demanding wild apple trees grow in riparian forests and on open spaces. They prefer mild humid climate conditions and were widely distributed over Europe and West Asia, where they diverged into numerous types. The question of the cultivation of apples is not yet solved, but it is most possible that apple domestication was superimposed on wild progenitors (Juniper and Mabberly, 2006, 53f.; Zohary and Hopf, 2000). In Europe, cultivation was furthered through the Mediterranean garden culture of the Romans, but beforehand, in the European Neolithic and Bronze Age, only the wild crab apple was available. In general, charred apples have been regularly proven for the Neolithic in Europe (e.g. Bakels, 2000; Brombacher, 1995, 93), but for the Northern German FBC evidence for apple consumption is rare. Imprints of apple pips were detected in ceramics from two FBC enclosures (Kroll, 1976; Kučan, 2002). The only evidence beside that published here originates from the late FBC settlement of Wangels LA 505 (ca. 2800 cal BC), situated on an island in the Oldenburger Graben close to Oldenburg-Dannau LA 77 (Kroll, 2007). Investigations of charcoal from Neolithic sites in Northern Germany as well as from Linear Band ceramic sites in Central Germany show increased values for the Pomoideae-type, which include the wood of apple trees (Kreuz, 1990, 194; Salavert, 2011; (Jansen and Nelle, 2014). Apple trees benefitted from human activities such as forest opening.

Wild apple trees are endangered plants wherever wild or domestic large herbivores are present. All wild fruit trees are resistant to the browsing of large herbivores as they all form shoots from a stool, have new growth from roots or display both – only wild apple does not seem to have these qualities (Vera, 2002, 339f.). The preference of large herbivores for apple consumption is proven by modern observations, e.g. of browsing European bison in the Caucasus region (Heptner et al., 1966) or for the "Primeval Forest Sababurg" in Hessia, Germany, where numerous apple trees that were mapped in the 1930s were reduced to four flowering trees in the 1970s due to the browsing of wild animals (Flörcke, 1967 after Vera, 2002, 215f.). The topographical situation in the wetland area of the Oldenburger Graben offered limited space outside domestic sites for the growth of apple trees, space that had to be shared with domestic animals (see chapter 4.4; for the relevance of domestic animals in the FBC see Hartz et al., 2007). Thus, there was a need for careful management and protection of apple trees. It remains to be proven whether even managed crab apple groves may have existed in close vicinity to the FBC settlements to hinder browsing by (domestic) animals and to ensure the availability of the much appreciated fruits.

5.3. *Disposal/deposition practices*

Finally, the Oldenburg-Dannau well was filled with domestic waste of variable quality that precluded is further use as a reservoir for water. The infilling process is assumed to have occurred during a rather short time period at around ca. 3050 cal BC – probably at a maximum within just a couple of days as any traces of natural sedimentation are missing – and comprised various deposition events, represented by the individual infill layers. Interestingly, most of these layers represent certain aspects of food processing. At first, a mixture of charred apples and daub, i.e. remains associated with kiln drying, was filled in the lowest third of the pit (layers 2, 4, 5). Hereby, layer 2 can be described as a single infill event during which more or less exclusively charred plant remains were disposed followed by layer 4, which was rich in daub, maybe representing remains of the kiln. Subsequently, a high number of quern fragments, again artefacts related to food processing, were disposed in layers 4 and 5. In this context, the high content of cereal-type pollen is noteworthy. Its preservation suggests that it does not derive from the threshing remains which were burnt. Due to the generally poor pollen dispersal of cultivated grasses, it is argued that this reflects pollen input connected with the querns and rubber stones rather than aerial input. This, in turn, indicates that the querns were probably in use just shortly before they were destroyed and deposited. In a next step, sediment with ceramics and other artefacts, indicating usual household items, was deposited (layers 7 and 8). Layer 9 again contained charred apple and querns remains and might therefore represent disposal of mixed material originally associated with previous infilling events, i.e. layers 3–5. Layer 12, rich in limnic and marine mollusc remains, might reflect a further component of the Neolithic diet: The preservation of fresh water algae and the complete bivalve shells indicate that the material was probably rather fresh when it was disposed. The final layer 13 is dominated by charred cereal grains. It is noteworthy that threshing remains are comparatively rare in relation to the previous layers.

The outlined relationship raises the question whether the deposition process was purely a coincidence or if intentional deposition might have played a role. Despite the fact that a division between a profane and a sacral world might be a misleading concept for Neolithic societies and that possibly every utilitarian purpose could also have had a non-utilitarian meaning, in the following, three contrary scenarios – comprising profane and sacred views – will be discussed: a) the infilling represents an act of profane disposal within normal settlement activity; b) the infilling is related to the destruction/abandonment of the settlement; c) the infilling is part of a normal ritual activity of the local group.

a) In the case of the first scenario, the infilling represents the disposal of domestic waste in a no longer used well. Hereby, the degree of shattered pieces of ceramics, the flint production waste and no longer usable utensils point to a profane character of the disposed material, i.e. artefacts. Furthermore, the infilling of the well contains no direct indication of repeated, ritual, non-utilitarian courses of action, as observed, for example, for ritual depositions in the context of prehistoric activities (e.g. Bradley, 2007; Veit, 1996). Difficult to explain in this scenario, however, are the deliberately destroyed querns and the human femur in the disposed material.

b) In the case of the second scenario, an event such as an assault by competing groups or a deliberately planned abandonment of the site by the inhabitants, could have led to a quick infill, including "fresh" and deliberately destroyed material. The great quantity of burnt plant remains could have derived from a destructive fire, intended by the leaving inhabitants or set by competing groups. The destroyed querns could be interpreted as an act of ritualised destruction of the economic subsistence. In the same way, the deposition of the human femur could reflect a symbolic desecration and/or defilement of an ancestor, if the burial is interpreted as part of an ancestor cult.

c) Whereas in the former two scenarios, the previous function of the well feature probably had no significance for the subsequent use as a disposal area, this could have been different in the case of a special ritual deposition of selected material, which would be associated with a ritual praxis of the general ritual concept of the FBC community. The connection between water and evidence for ritual deposition is a well-known feature for the FBC (Bakker, 1998). For the FBC North Group, this is documented by depositions of vessels in combination with animal and human bones in bogs,

lakes, and springs (Bakker, 1998; Rasmussen and Skousen, 2012). Furthermore, the deposition of food and related artefacts (e.g. querns and rubber stones) as well as the intentional destruction of deposited artefacts are discussed as aspects of such ritual depositions. Concerning ceramics, however, ritual depositions could be associated both with complete or broken vessels.

Table 4 points to the pros and cons of different interpretations of the deposition process in the well of Oldenburg-Dannau.

6. Conclusions

The multi-disciplinary analysis of a well and its filling dated to the 31st c. cal BC resulted in important insights concerning Middle Neolithic behaviour and economy at coastal domestic sites of the FBC-North Group, which is all the more significant as well-dated contexts of domestic sites are seldom known from this period:

- **Water management:** Water management strategies of FBC-societies included the construction of wells. The necessity for such structures could have been triggered by water pollution by humans and animals or environmental conditions like the salinity of the water surrounding the islands and peninsulas. The latter is most probable in the case of Oldenburg-Dannau. Beside aspects of ritual activities in wet areas, the Oldenburg-Dannau LA77 well substantiates the economic value of water management during the late FBC within a domestic site.
- **Subsistence**: The emmer/barley macro-remains and the huge amount of querns, which were broken and deposited immediately after use (judged from cereal pollen), underlines the value of cereal production and processing particularly in late FBC economies. The evidence of the composition of the well deposit is comparable with the huge amount of querns and macro-remains, associated with the other features of the site. Even if one would prefer to interpret the well's infill as a ritual deposition, the cluster of objects and remains describe the importance of agriculture for the acting community. Obviously, in contrast to early FBC, small scale crop growing was not practiced. Instead, the area under cultivation was enlarged. This change may have been induced by a technical innovation with a shift from using the hoe to the plough as a main tool (Andersen, 1997; Furholt and Müller, 2011, 2011; Mischka, 2011). The tilling left the soil alongside the plough marks untouched so that perennial plants could fill this area. Thus, they could easily expand on the fallow land that was most probably used for grazing domestic animals. In the special case of Oldenburg-Dannau LA77, arable land must have been positioned not only on the island, but also on surrounding land. In consequence, a spatial organization of the village economy was necessary with respect to field distribution, transportation, property rights, and commodity distribution. Beside cereal production, the organized harvest of apple trees played an important role. This indicates an ongoing process of taming wild species that may have lead to the creation of apple groves. The importance of animal husbandry and the exploitation of marine resources (shells) are also documented.

Table 4
Pro (+), neutral (○) and contra (−) arguments for different interpretations of the well infill.

	Profane	Intended in one moment	Ritual
Ceramic (no complete pot, few decorated sherds)	+	○	+
Silex (mainly destroyed artefacts, production waste)	+	○	+
Daub (partly burned)	+	+	○
Food residue (shells, snails, animal bones, cereals, apples)	+	○	+
13 Querns and 2 rubbers (all destroyed)	−	+	+
Human femur (taken from the nearby grave)	−	+	+
Deposition in a former well	○	+	+

6.1. *Deposition*

As the well had no casing, it cannot have been in use for more than a few days or weeks. The backfilling of the well must have taken place within a short timeframe. According to the pollen composition, the deposition took place in summer and autumn. The findings make a disposal of waste one potential explanation. The quantity of deposited finds of the well is comparable to the artefact quantities from the entire site. In addition to the remains of tools and tool production, a number of querns are noteworthy. The "fresh" character of broken querns might point to depositional processes which were linked to a sudden destruction of the site (Brozio, 2010, 2011). As all layers contain food remains and with respect to the destruction of querns and findings of ceramics, the backfill may also be interpreted as a ritual deposition in an area near water as often recorded from FBC sites. As shown above, different scenarios are possible for the backfilling of the well. Thus, the single high quality archive enabled us to describe additional details of a context, which are observable for further contexts. In consequence, the feature presented here as a high quality archive enabled a comprehensive interpretation of subsistence economies and their environmental conditions.

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